

**Water Year 2005
Overview of Surface Water
Monitoring Data for SC, SAR and Flow
in the Rosebud Creek Watershed**



This cover photo shows an aerial photograph of the Rosebud Creek valley near the USGS's Rosebud Creek near Kirby station.

**Prepared by: Andrew L. Bobst, Hydrologist, BLM-Miles City Field Office
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Introduction

When Coal Bed Natural Gas (CBNG) is developed it is necessary to reduce the pressure to allow the methane to desorb from the coal. This is typically achieved by pumping groundwater from the coal bed aquifer being developed, since this reduces the hydrostatic pressure within the coal seam and creates a pressure gradient within the aquifer that causes methane to flow towards the pumping wells. This coal seam water in the Montana portion of the Powder River Basin is typically moderately saline, having a Specific Conductance (SC; which is proportional to salinity) on the order of 2,000 microSiemens per centimeter ($\mu\text{S}/\text{cm}$). High salinity irrigation water may result in decreased crop yields depending on the crop being grown (See Fig. 1). Since the MDEQ regulations define Electrical Conductivity (EC) as “the ability of water to conduct an electrical current at 25°C” the SC values discussed in this report are directly comparable to the EC standards. CBNG water in Montana is a sodium-bicarbonate (Na-HCO_3) type water, while surface waters are typically relatively balanced. This dominance of sodium cations cause this water to have a high Sodium Adsorption Ratio (SAR; which is a complex ratio of Na to $\text{Ca}+\text{Mg}$); typically between 30 and 60. High SAR values may cause impacts to soil structure, and impair the ability for clay rich soils to infiltrate water (see Fig. 2). There is also little sulfate in the water in productive coal seams (VanVoast, 2003). Much of the produced water is managed through treated or untreated discharge to surface waters under National Pollutant Discharge Elimination System (NPDES) permits.

In Montana, NPDES permitting is conducted by the Montana Department of Environmental Quality (MDEQ) under the Montana Pollutant Discharge Elimination System (MPDES) permit program. There are currently no permits for CBNG discharge to Rosebud Creek.

In response to the potential for CBNG development in this area, the MDEQ and Northern Cheyenne Tribe have developed surface water quality standards for EC and SAR in the Rosebud Creek watershed. These standards provide criteria against which to compare the monitoring data. These standards are summarized in Table 1 below. It should be noted that the MDEQ standards have been reviewed and approved by the United States Environmental Protection Agency (EPA), and therefore have Clean Water Act standing; however, the Northern Cheyenne Tribe has not been granted “Treatment as a State” (TAS) status by the EPA, therefore, the Northern Cheyenne standards do not have Clean Water Act standing. Also, note that irrigation season standards are different from the non-irrigation season, and the MDEQ and Northern Cheyenne have defined the irrigation season differently. It should be noted that these values are used solely as a point of comparison; the comparisons in this report do not constitute regulatory determinations.

The Montana Board of Environmental Review (BER) has modified the standards which apply to CBNG in Montana; however this report only considers those standards which were in place in water year 2005. The most substantial change adopted by the BER was to designate EC and SAR “harmful” parameters, which causes non-degradation rules to apply. The EPA has not yet approved the BER’s modifications.

Table 1: MDEQ and Northern Cheyenne Surface Water Standards Applicable for Water Year 2005 for EC and SAR in the Rosebud Creek Watershed

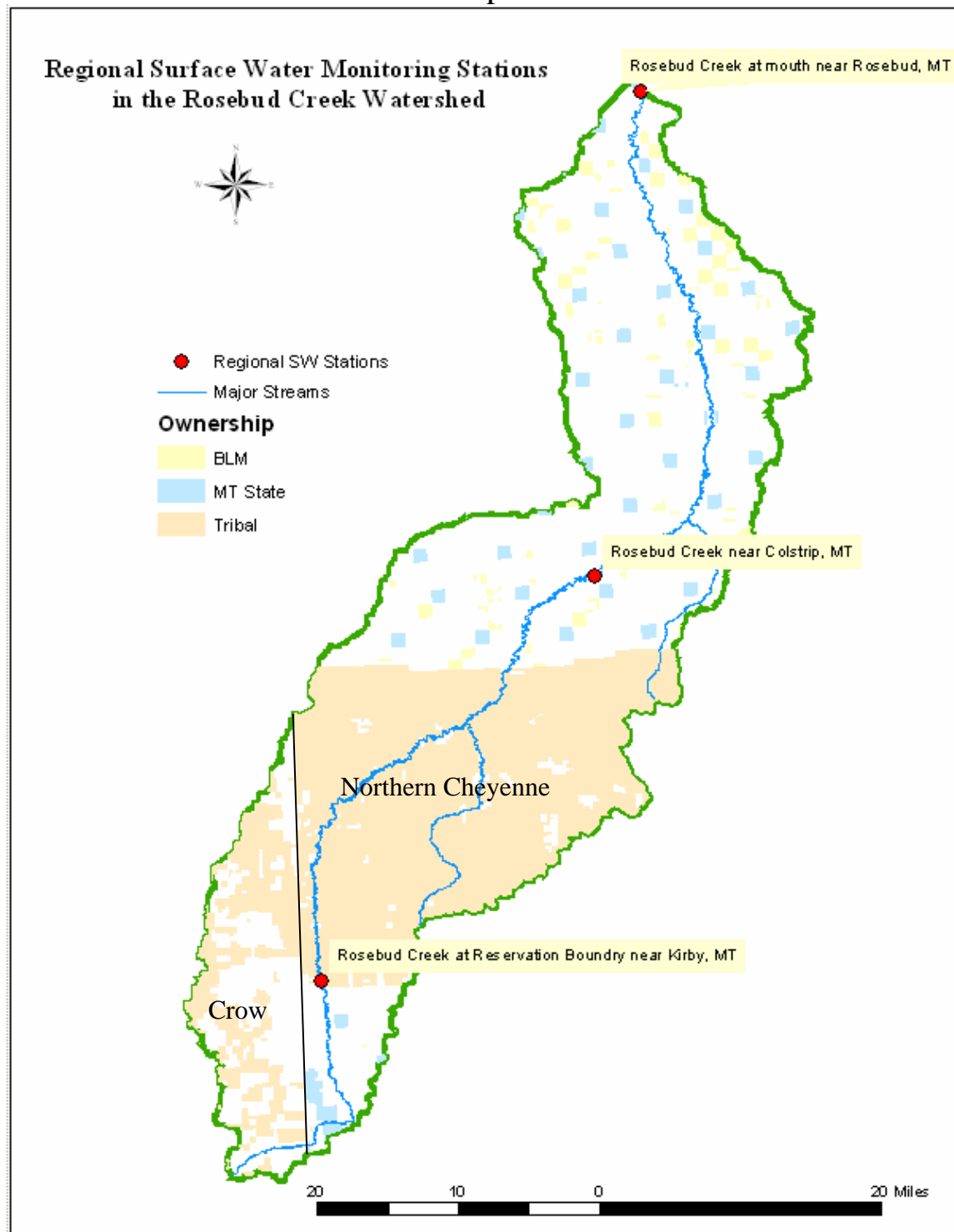
Irrigation Season ¹					
	MDEQ		Northern Cheyenne		
	Rosebud Creek	Tributaries	Southern Boundary	Northern Boundary	Tributaries
EC (uS/cm)					
Monthly Average	1000	500	1000	1500	1500
Not to Exceed	1500	500	2000	2000	2000
SAR					
Monthly Average	3.0	3.0	---	---	---
Not to Exceed	4.5	4.5	2.0	3.0	3.0

Non-Irrigation Season ¹					
	MDEQ		Northern Cheyenne		
	Rosebud Creek	Tributaries	Southern Boundary	Northern Boundary	Tributaries
EC (uS/cm)					
Monthly Average	1500	500	---	---	---
Not to Exceed	2500	500	2000	2000	2000
SAR					
Monthly Average	5.0	5.0	---	---	---
Not to Exceed	7.5	7.5	2.0	3.0	3.0

1: The irrigation season specified by the MDEQ is from march 1st to October 31st while the irrigation season specified by the Northern Cheyenne is from April 1st to November 15th.

The Interagency working group for CBNG has identified regional surface water monitoring stations for the Rosebud Creek watershed. These stations, with their status for water year 2005 (10/1/04-9/30/05) are listed on Table 2 below. Data collected at these stations included continuous flow, continuous specific conductance (SC), and analytical sampling. Analytical sampling includes the measurement of flow, field parameters (SC, pH, temperature, etc) and includes the collection of water-quality samples. Although these samples were analyzed by the USGS for many parameters, this report will focus on SC, SAR, and flow. SC and SAR are considered to be the parameters most likely to be affected by CBNG development (MDEQ, 2003b), and SC and SAR in the natural system fluctuate significantly with flow. The data tables section includes the data collected for field parameters, common ions, and metals (filtered and unfiltered). The monitoring at these stations was funded by the USGS, the BLM, and the Northern Cheyenne Tribe. An expanded set of analytical data are available from the USGS at <http://waterdata.usgs.gov/mt/nwis/>.

Map 1



Map 1 shows the Rosebud Creek Watershed and its major surface ownership. The locations of the 3 surface water monitoring sites which are the subject of this report are also shown.

Table 2: Regional USGS Surface Water Monitoring Stations for the Rosebud Creek Watershed during Water Year 2005

Station Number	Station Name	Status
06295113	Rosebud Creek at reservation boundary, near Kirby, MT	Flow, EC and QW
06295250	Rosebud Creek, near Colstrip, MT	Flow ¹
06296003	Rosebud Creek at mouth, near Rosebud, MT	Flow and QW

Flow = Continuous flow

EC = Continuous EC monitoring (seasonally)

QW = Water Quality Sampling

¹ = SC measurements were made at 06295250 during gauge maintenance visits

Data Review

For all sites, please see the figures section for graphical display of the data. Tabulated summary statistics for the sites are provided on Table 4 below.

For each station a summary of the daily mean flow, and SC, data collected during water year 2005 is presented if available. Analytical SC, SAR and flow data are also presented. Analytical samples are compared to the MDEQ “not to exceed” (NTE) surface water standards for EC and SAR. For comparison to the mean monthly EC and SAR standards the mean monthly values are calculated as the simple average of all the mean daily and analytical measurements recorded during each calendar month. Note that within the figures section the daily mean and analytical data are combined when discussing the range of values recorded. SC vs. Flow, SAR vs. Flow, and SC vs. SAR with historical data are presented in graphical form to allow evaluation of 2005 data in context.

Since SC and SAR are dependent on flow, it is important to recognize up front that water year 2005 was somewhat wetter than 2004, though flows were still less than long-term averages. Comparisons of flows for these years vs. the period of record are shown on Table 3 below. If comparison is made between water quality data from different years, it is important to also take flow into account.

Table 3: Comparison of Flows

Station Name	Annual Mean Flow (cfs)		
	WY 2004	WY 2005	Period of Record
Rosebud Creek near Kirby, MT	1.70	2.98	5.83
Rosebud Creek, near Colstrip, MT	3.45	5.52	22.2
Rosebud Creek, near Rosebud, MT	4.25	9.77	26.2

cfs = cubic feet per second

Rosebud Creek near Kirby

Flow and SC were measured continuously at this site for at least a portion of the year. Water-quality samples were also collected. Mean daily flow values ranged from 0 to 116 cfs, with the mean being 3.0 cfs (see Fig. 3).

Mean daily mean SC data collected at this station ranged from 638 to 1190 $\mu\text{S}/\text{cm}$, with a mean value of 1005 $\mu\text{S}/\text{cm}$ (see Fig. 4). Analytical SC values at this site ranged from 894 to 1170 $\mu\text{S}/\text{cm}$, with the mean being 1042 $\mu\text{S}/\text{cm}$. Analytical SAR values at this site ranged from 0.4 to 1.0 with the mean being 0.8 (see Figs. 4-7).

Recorded SC values did not exceed the MDEQ EC NTE standards. Recorded SAR values did not exceed the MDEQ NTE standard. Mean monthly SC values were in excess of the MDEQ mean monthly EC standard during October, April, May, and August. Mean monthly SAR values did not exceed the mean monthly SAR standards (see Fig. 4).

SC vs. Flow, SAR vs. Flow, and SC vs. SAR charts in the figures section present the 2005 data along with historical data (see Figs. 25-27).

Table 4: Summary of USGS Monitoring Data in the Rosebud Creek Watershed for Water Year 2005

		Daily Mean		Water Quality Samples			Monthly Mean ⁺	
		Flow (cfs)	SC ($\mu\text{S}/\text{cm}$)	Flow (cfs)	SC ($\mu\text{S}/\text{cm}$)	SAR	SC ($\mu\text{S}/\text{cm}$)	SAR
Rosebud Creek at Reservation Boundary near Kirby, MT	n	365	118	11	11	11	11	11
	min	0.0	638	0.0	894	0.4	753	0.5
	max	116	1190	51	1170	1.0	1170	1.0
	mean	3.0	1005	6	1042	0.8	1022	0.8
	median	1.0	1010	1.0	1040	0.9	1023	0.9
Rosebud Creek near Colstrip, MT	n	365	---	4	4	---	---	---
	min	0.0	---	3.9	1920	---	---	---
	max	50	---	7.4	2670	---	---	---
	mean	5.5	---	5.1	2150	---	---	---
	median	3.5	---	4.6	2005	---	---	---
Rosebud Creek at mouth, near Rosebud, MT	n	365	---	9	9	5	8	4
	min	0.0	---	0.0	427	3.0	597	4.3
	max	297	---	226	4300	8.0	4300	8.0
	mean	9.8	---	48	2376	5.6	2519	5.9
	median	0.3	---	0.3	2490	5.6	2770	6.2

Indicates exceedance of MDEQ Irrigation Season Standards.

+ = Monthly mean values are calculated by taking the simple mean of all mean daily and analytical values collected during each calendar month.

SAR = Sodium Adsorption Ratio

SC = Specific Conductance

$\mu\text{S}/\text{cm}$ = microSiemens per centimeter

Rosebud Creek near Colstrip

Flow was measured continuously at this site. SC measurements were made during site visits. Mean daily flow values ranged from 0 to 50 cfs, with the mean being 5.5 cfs (see Fig. 8).

SC values at this site ranged from 1920 to 2670 $\mu\text{S}/\text{cm}$, with the mean being 2150 $\mu\text{S}/\text{cm}$. Analytical SAR values were not obtained at this site (see Fig. 9-10).

Recorded SC values exceeded the MDEQ EC NTE standards for three of the four measurements. Mean monthly SC values were all in excess of the MDEQ mean monthly EC standards (see Fig. 9).

A SC vs. Flow chart in the figures section presents the 2005 data along with historical data (see Fig. 10).

Rosebud Creek near Rosebud

Flow was measured continuously at this site. Water-quality samples were also collected. Mean daily flow values ranged from 0 to 297 cfs, with the mean being 9.8 cfs (see Fig. 11).

Analytical SC values at this site ranged from 427 to 4300 $\mu\text{S}/\text{cm}$, with the mean being 2376 $\mu\text{S}/\text{cm}$. Analytical SAR values at this site ranged from 4.3 to 8.0 with the mean being 5.9 (see Figs. 12-15).

Recorded SC values were above the EC NTE standard for five of the nine samples collected. Recorded SAR values were above the SAR NTE standard for four of the five samples collected. Mean monthly SC values were in excess of the mean monthly EC standard during November, December, February, May, July, August and September. Mean monthly SAR values were in excess of the mean monthly SAR standard during June, July, and August (see Fig. 12).

SC vs. Flow, SAR vs. Flow, and SC vs. SAR charts in the figures section present the 2005 data along with historical data (see Figs. 13-15).

Conclusions

During Water Year 2005 (October 2004-September 2005) flows within Rosebud Creek watershed were higher than 2004, but still lower than historical averages. EC and SAR can be correlated with flow so an evaluation of EC and SAR must also take flow into account.

A comparison to the MDEQ surface water standards for EC and SAR showed that at least one of these standards are exceeded part of the time at every station. The uniform exceedance of these standards, even though no CBNG development has occurred in this watershed indicates that natural and/or non-CBNG conditions are responsible for these exceedances.

A statistical trend analysis was not conducted for this data; however an interpretive report is scheduled to be completed in 2007 which will include data through Water Year 2006.

References

- Ayers, R. S., and Westcot, D.W., 1985, Water Quality for Agriculture, FAO Irrigation and Drainage paper 29 (Rev 1), Food and Agriculture Organization of the United Nations.
- Hansen, B.R., Gratton, S. R., and Fulton A., 1999, Agricultural Salinity and Drainage, University of California Irrigation Program, University of California, Davis.
- MDEQ, 2003b, Record of Decision for the Montana Statewide Oil and Gas Environmental Impact Statement (http://www.deq.state.mt.us/coalbedmethane/pdf/RODAug7_03.pdf)
- VanVoast, W.A., 2003, Geochemical signature of formation waters associated with coalbed methane, AAPG Bulletin, v. 87, no. 4 (April 2003), pp. 667–676.

Reviewers

Banning Star

MDEQ, Helena, MT

David Nimick

USGS, Helena, MT

Data Tables

Rosebud Creek near Kirby (06295113)
Water Year 2005 Field Parameters

Date	Discharge cfs	EC (uS/cm)	DO (mg/L)	pH
10/14/2004	0.51	1060	7.3	8.1
11/5/2004	0.59	1020	---	8.3
12/3/2004	2 E	1170	11.8	7.9
2/8/2005	1 E	1040	11.3	8.0
3/8/2005	1.5	997	9.8	8.0
4/5/2005	1.1	1070	7.2	8.1
5/16/2005	51	894	7.6	8.1
6/9/2005	8.1	1010	7.9	8.3
7/26/2005	0.81	1010	5.3	8.1
8/24/2005	0.21	1080	5.7	7.9
9/7/2005	0.02	1110	7.3	8.1

--- = data not collected

E = estimated value

Rosebud Creek near Kirby (06295113)
Water Year 2005 Common Ions

Date	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	SAR	K (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Fluoride (mg/L)	Silica (mg/L)	Alkalinity (mg/L)
10/14/2004	79.9	91.1 E	49.2	0.9	11.2	4.7	94	0.9	12.7	546 E
11/5/2004	80.2	83.8	46.0	0.9	9.9	4.7	103	0.9	17.0	523
12/3/2004	86.9	93.8	52.6	0.9	9.5	4.9	138	0.9	19.3	565
2/8/2005	79.4	85.6	43.2	0.8	8.3	4.1	137	0.8	16.3	492
3/8/2005	76.7	83.2	42.7	0.8	7.9	3.7	136	0.7	16.1	467
4/5/2005	75.8	84.3	45.9	0.9	8.4	4.0	138	0.8	16.2	490
5/16/2005	71.3	66.8	21.8	0.4	10.8	2.6	199	0.5	16.9	285
6/9/2005	72.2	81.9	30.2	0.6	7.5	3.4	185	0.7	9.3	407
7/26/2005	56.3	81.8	47.3	0.9	8.4	3.5	129	0.9	14.4	471
8/24/2005	66.5 E	90.2	52.6	1.0	10.9	3.9	134	0.9	11.9	508
9/7/2005	67.2	94.5	52.5	1.0	11.2	4.7	137	0.9	8.7	490

E - Estimated value

Rosebud Creek near Kirby (06295113)
Water Year 2005 Primary Metals (unfiltered)

Date	Al (ug/L)	As (ug/L)	Ba (ug/L)	Be (ug/L)	Fe (ug/L)	Mn (ug/L)	Se (ug/L)
5/16/2005	865	2.0	132	0.09	2340	167.0	1.1 <
6/9/2005	45	1.0	119	0.06	244	27.8	0.8 <
7/26/2005	94	2.0	89	0.06	246	39.5	0.6 <
8/24/2005	190	2.4	105	0.06	352	67.7	0.4 <
9/7/2005	81 <	2.1	99	0.06	265	44.5	0.18 E

--- - data not collected

E - Estimated value

< - Actual value is known to be less than the value shown.

Rosebud Creek near Kirby (06295113)
Water Year 2005 Primary Metals (filtered)

Date	Al (ug/L)	As (ug/L)	Ba (ug/L)	Be (ug/L)	Fe (ug/L)	Mn (ug/L)	Se (ug/L)
5/16/2005	2	1.4	120	0.06	23	78.9	0.9 <
6/9/2005	6	1.3	100	0.06	28	20.0	0.3 <
7/26/2005	5	3.3	87	0.06	20	33.1	0.5 <
8/24/2005	1	2.3	98	0.06	26	40.4	0.2 <
9/7/2005	---	2.0	94	0.06	15	17.8	0.05

--- - data not collected

< - Actual value is known to be less than the value shown.

Rosebud Creek near Colstrip (06295250)
Water Year 2005 Field Parameters

Date	Discharge cfs	EC (uS/cm)
1/25/2005	4.8	2670
2/17/2005	3.9	2090
3/14/2005	4.3	1920
5/3/2005	7.4	1920

Rosebud Creek near Rosebud (06296003)
Water Year 2005 Field Parameters

Date	Discharge cfs	EC (uS/cm)	DO (mg/L)	pH
11/10/2004	0.32	1700	---	---
12/14/2004	0.08	3500	---	---
2/17/2005	0.24	2490	---	---
5/10/2005	226	427	9.5	8.3
5/18/2005	48	2100	8.8	8.4
6/9/2005	155	597	8.6	8.2
7/14/2005	0.2	2770	---	8.5
8/3/2005	0.3	3500	7.6	8.5
9/15/2005	0.01	4300	9.3	8.6

--- = data not collected

Rosebud Creek near Rosebud (06296003)
Water Year 2005 Common Ions

Date	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	SAR	K (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Fluoride (mg/L)	Silica (mg/L)	Alkalinity (mg/L)
5/10/2005	8.77	3.18	76.1	5.6	4.2	1.3 E	71	0.4	8.5	118
5/18/2005	102	149	203.0	3.0	15.4	12.6 <	802	0.6	16.5	407
6/9/2005	15.3	7.11	97.7	5.2	4.9	2.0 <	154	0.4	6.7 <	135
7/14/2005	79.5	143	399.0	6.2	12.5	16.5	1120	0.7	4.5	434
8/3/2005	73.8	183	565.0	8.0	14.4	23.5 <	1520	0.8 E	0.9 <	450

E - Estimated value

< - Actual value is known to be less than the value shown.

Rosebud Creek near Rosebud (06296003)
Water Year 2005 Primary Metals (unfiltered)

Date	Al (ug/L)	As (ug/L)	Ba (ug/L)	Be (ug/L)	Fe (ug/L)	Mn (ug/L)	Se (ug/L)
5/10/2005	57400	11	906	6.7	61300	1030	2.0 <
5/18/2005	2620	2	150 E	0.22	3410	194	1.4
6/9/2005	59800	10 <	1440	11.4	70100	1870	2.7
7/14/2005	454	1	145	0.12	509	50	1.0
8/3/2005	228	---	115	0.12	261	43.6	1.9

--- - data not collected

E - Estimated value

< - Actual value is known to be less than the value shown.

Rosebud Creek near Rosebud (06296003)
Water Year 2005 Primary Metals (filtered)

Date	Al (ug/L)	As (ug/L)	Ba (ug/L)	Be (ug/L)	Fe (ug/L)	Mn (ug/L)	Se (ug/L)
5/10/2005	---	0.8	23	0.06	37	2.6	1.1
5/18/2005	2	1.4	130	0.06	1630	12.7	0.7
6/9/2005	12	0.8	37	0.06	10 <	0.8	1.8 <
7/14/2005	3	1.5	147	0.12	18	15.4	0.9 <
8/3/2005	6 E	1.3	101	0.12	18	0.9	1.6

--- - data not collected

< - Actual value is known to be less than the value shown.

E - Estimated value

Figures

Figure 1: Comparison of Crop Yield to SC (Salinity) and Recorded 2005 SC Values in the Rosebud Creek Watershed

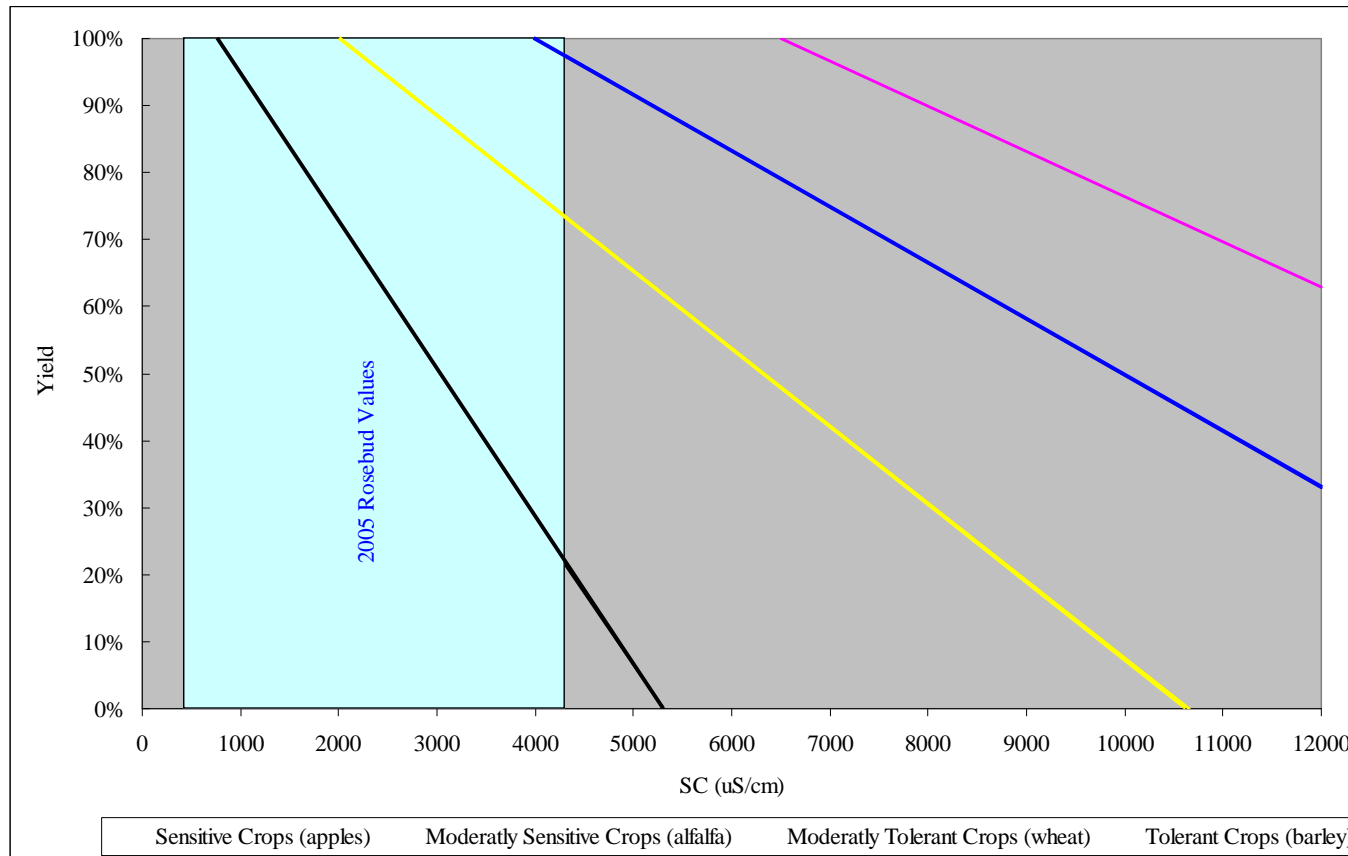


Figure 1 shows the range of SC values recorded during water year 2005 compared to yield vs. salinity curves for representative crops (Ayers and Westcott, 1999). Note that yield comparisons are made to that which would be attained using low salinity irrigation water, and assumes that all other factors are equal. Values ranged from 427 to 4300 uS/cm.

Figure 2: Comparison of Infiltration Criteria and Recorded 2005 SC and SAR Values in the Rosebud Creek Watershed

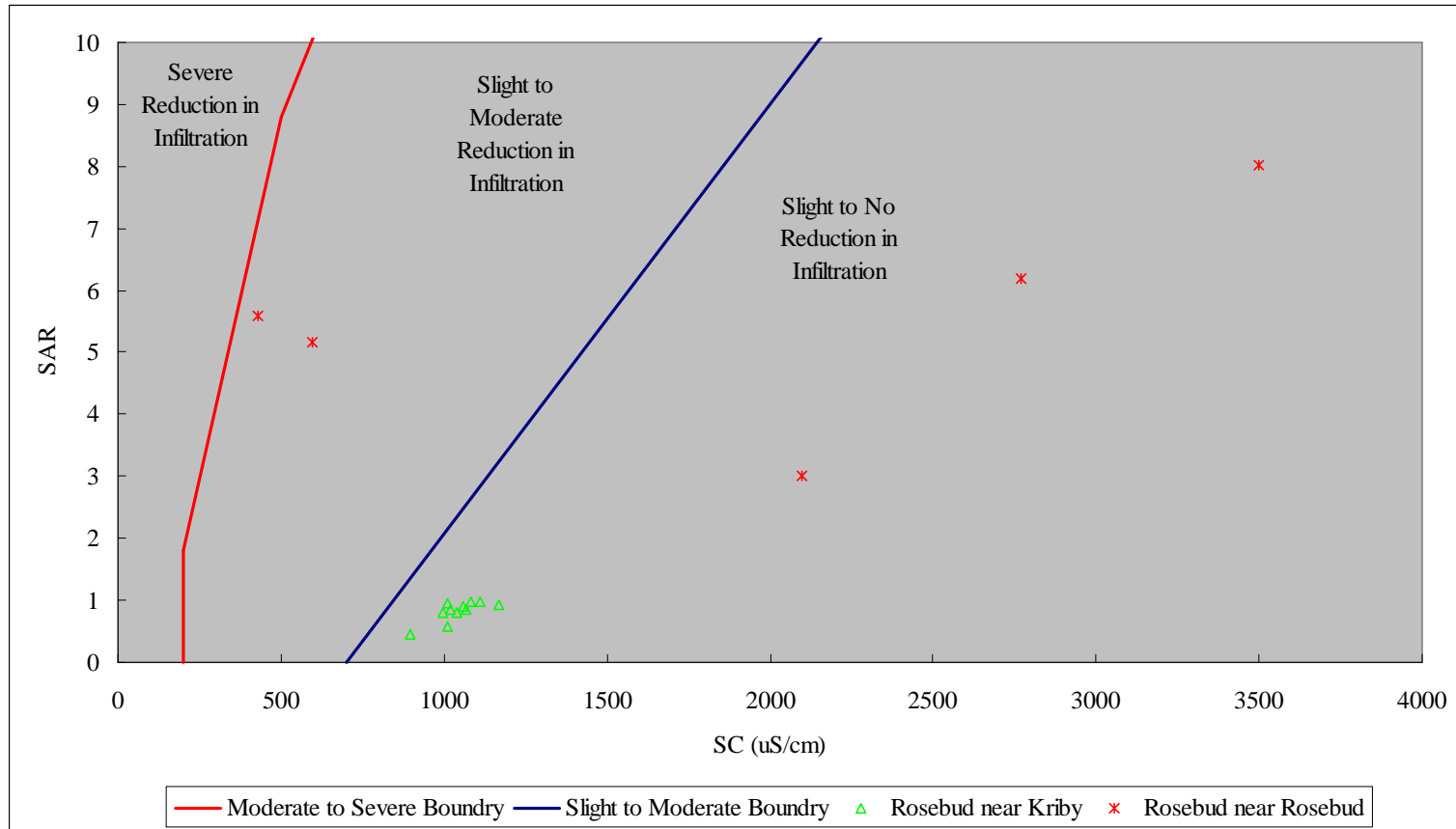


Figure 2 shows water quality data from water year 2005 in the Powder River Watershed compared to the infiltration criteria developed by Hanson et al. (1999). Most values fall within the Slight to No reduction in infiltration field; however two samples from the Rosebud station fall within the Slight to Moderate reduction field.

Figure 3: Rosebud Creek near Kirby

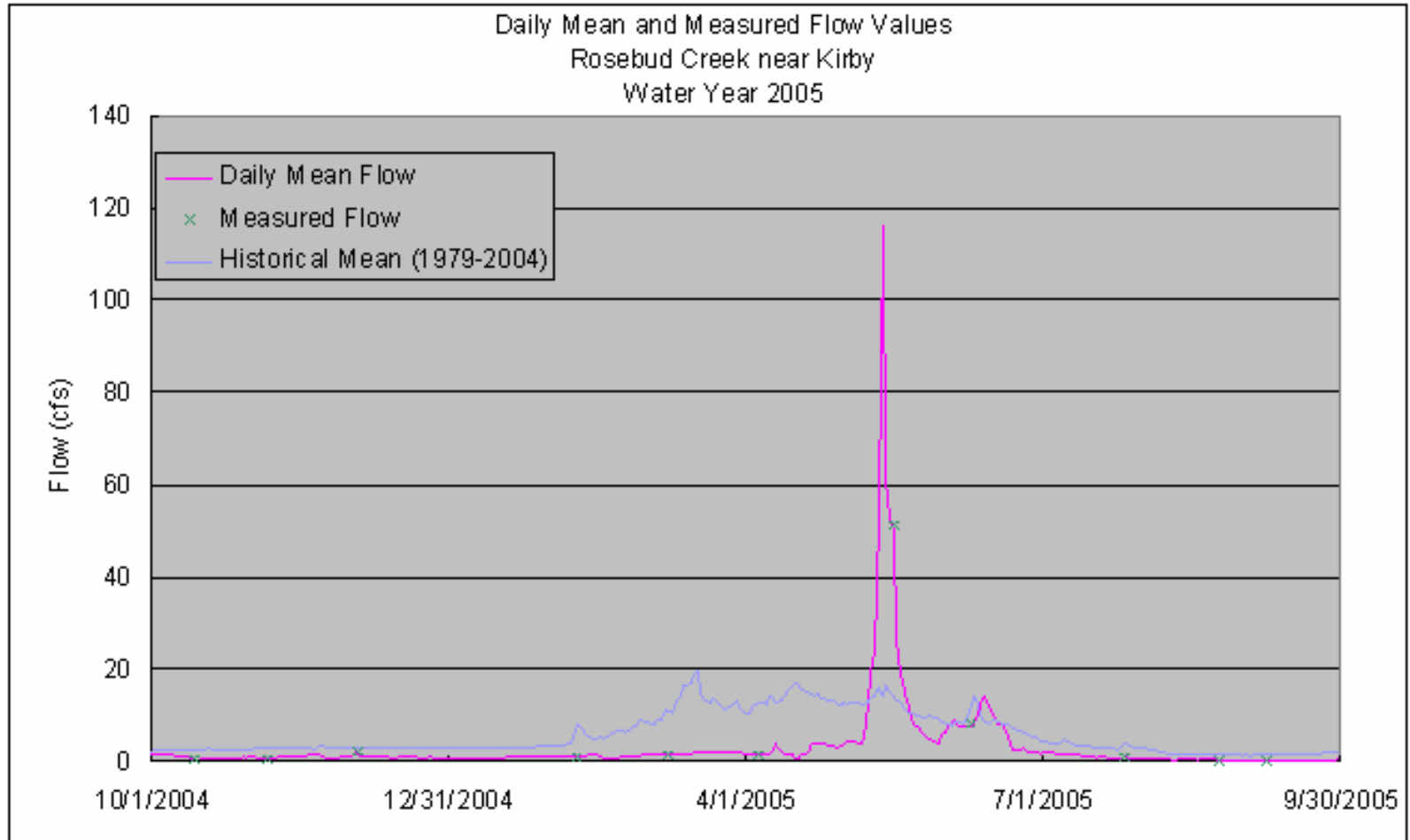


Figure 3 shows mean daily and field measurements of flow in a time series plot for water year 2005 for Rosebud Creek near Kirby. Mean daily flow values ranged from 0 to 116 cfs. The historical mean daily flow values are also shown to place the data in context.

Figure 4: Rosebud Creek near Kirby

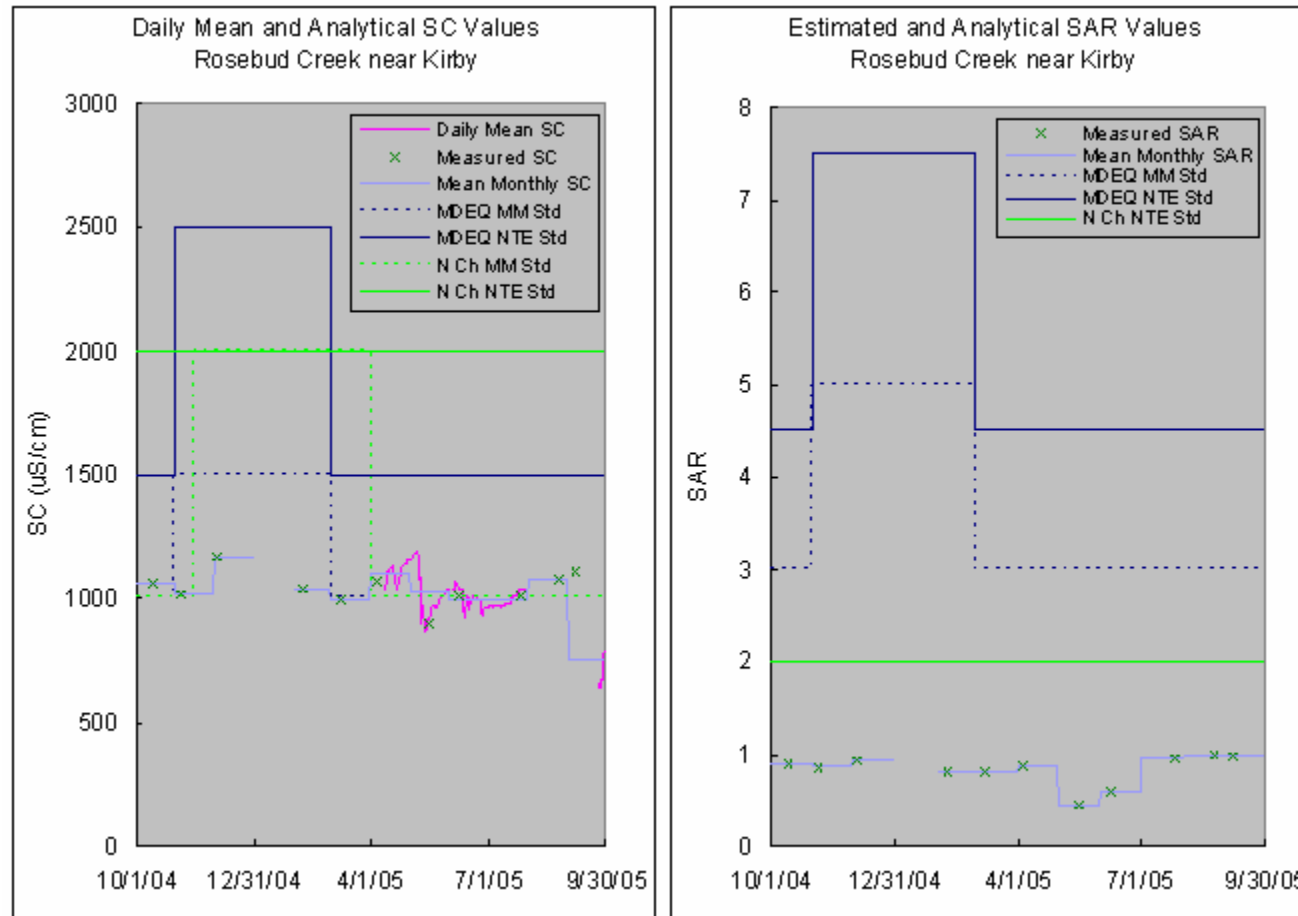


Figure 4 shows analytical and Daily Mean SC values (A) and analytical SAR values (B) in time series plots for water year 2005 for Rosebud Creek near Kirby. Mean Monthly SC and SAR values are also shown. SC values ranged from 638 uS/cm to 1190 uS/cm. SAR values ranged from 0.4 to 1.0. MDEQ and Northern Cheyenne standards are also displayed for comparison.

Figure 5: Rosebud Creek near Kirby

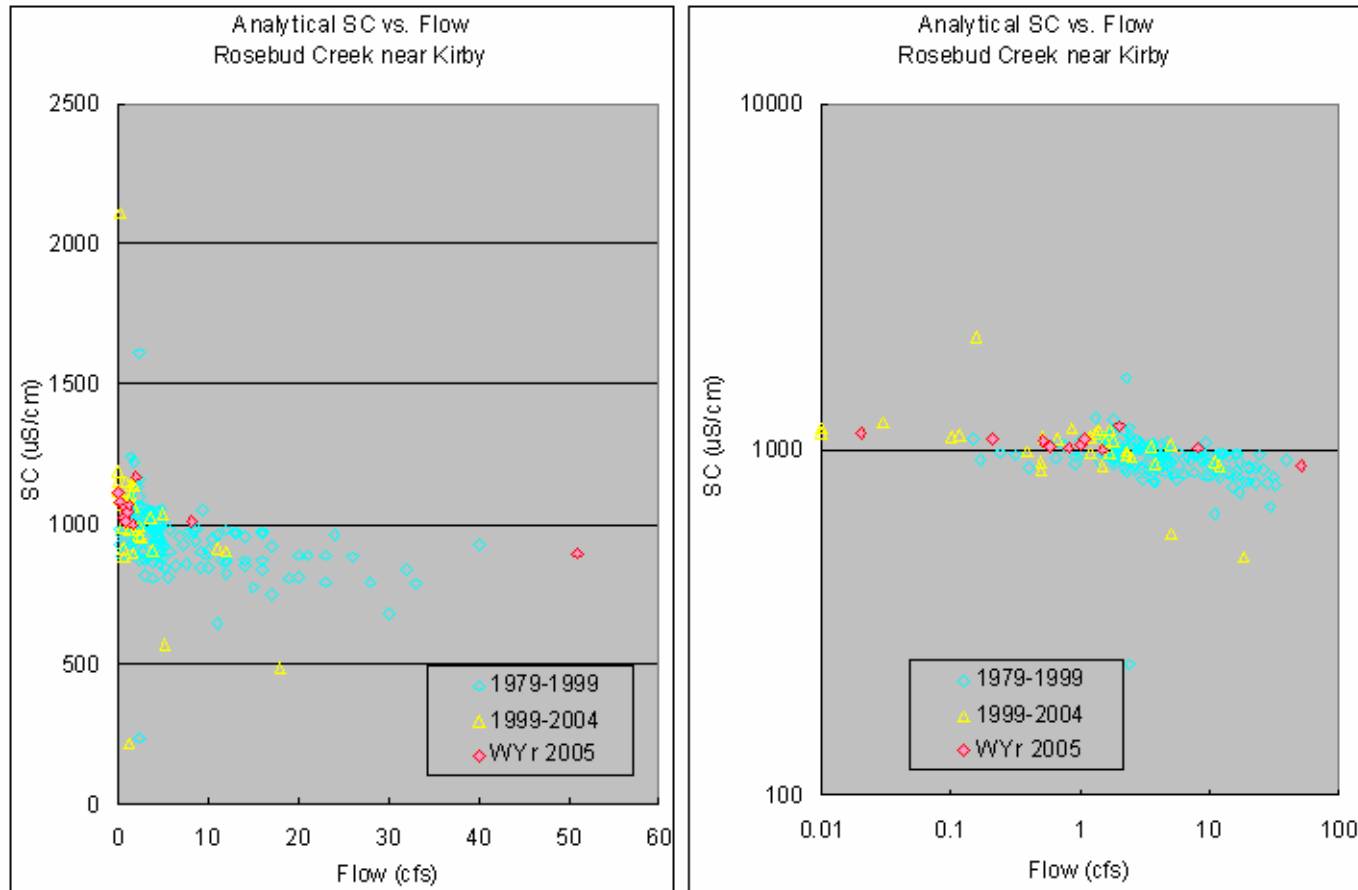


Figure 5 shows analytical SC vs. Flow data for water year 2005 for Rosebud Creek near Kirby. These data are charted on both linear (A) and logarithmic (B) scales. Historical SC vs. Flow data are also shown to place the data in context.

Figure 6: Rosebud Creek near Kirby

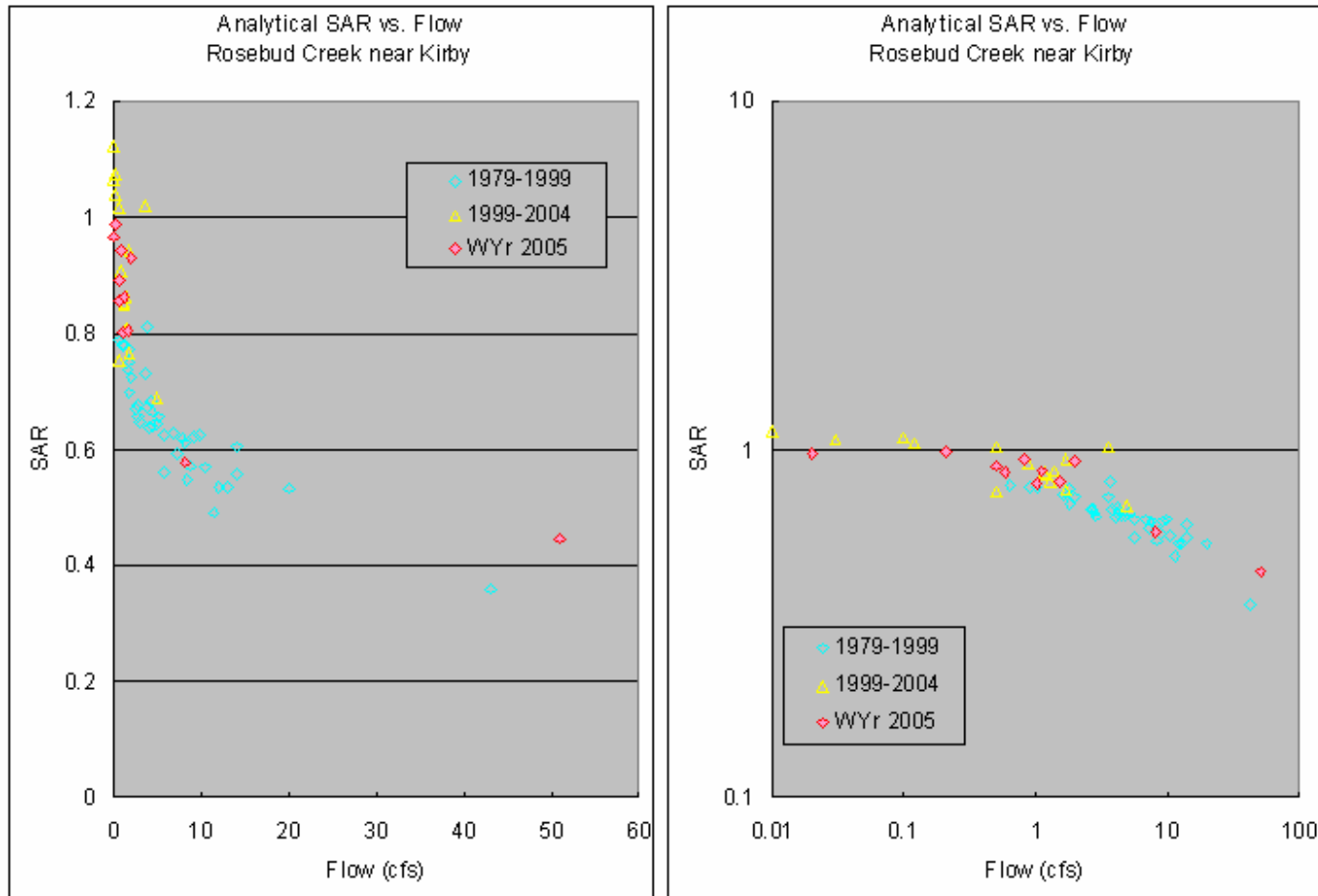


Figure 6 shows analytical SAR vs. Flow data for water year 2005 for Rosebud Creek near Kirby. These data are charted on both linear (A) and logarithmic (B) scales. Historical SAR vs. Flow data are also shown to place the data in context.

Figure 7: Rosebud Creek near Kirby

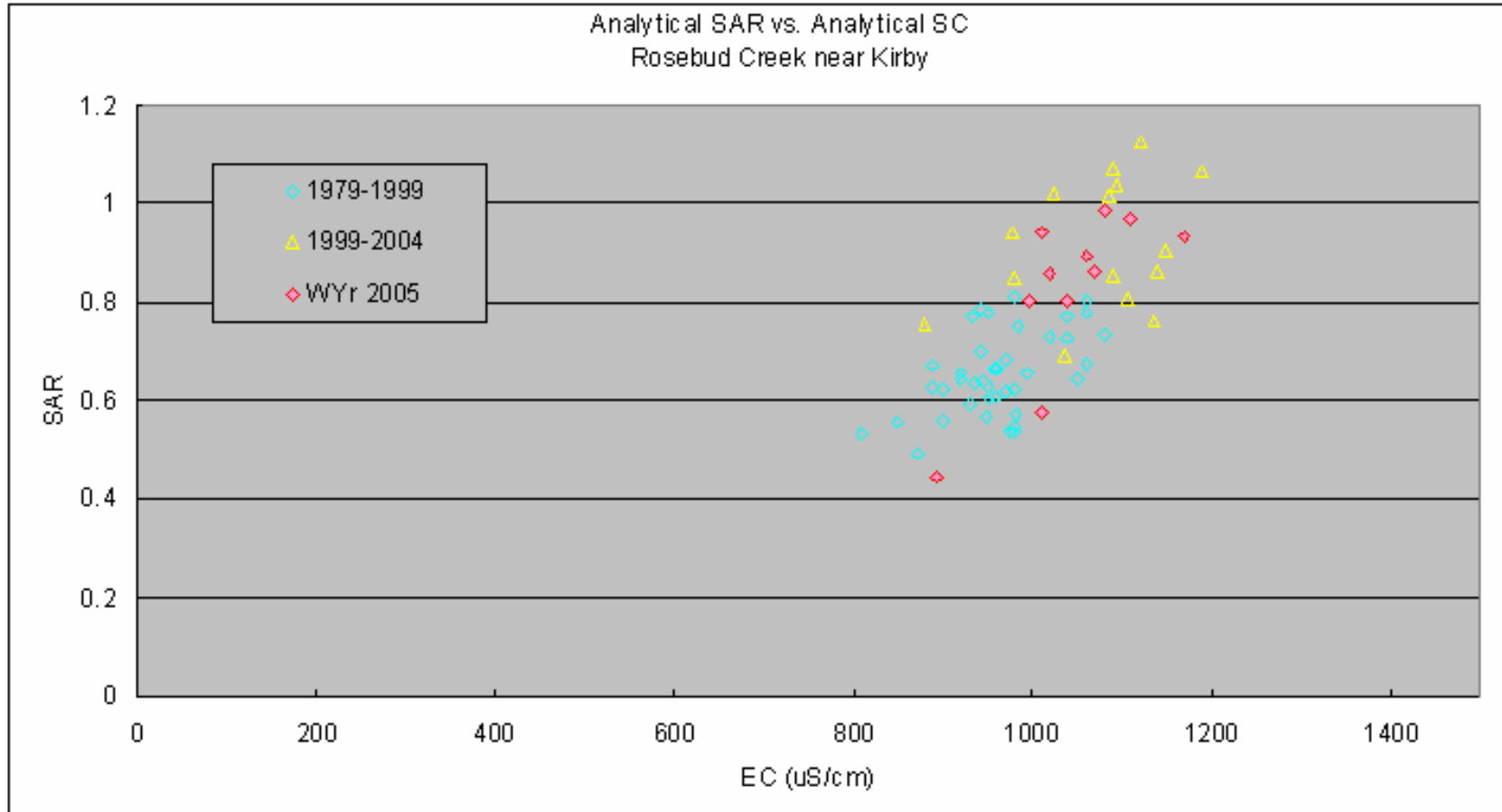


Figure 7 shows analytical SAR vs. analytical SC data for water year 2005 for Rosebud Creek near Kirby. Historical SAR vs. SC data are also shown to place the data in context.

Figure 8: Rosebud Creek near Colstrip

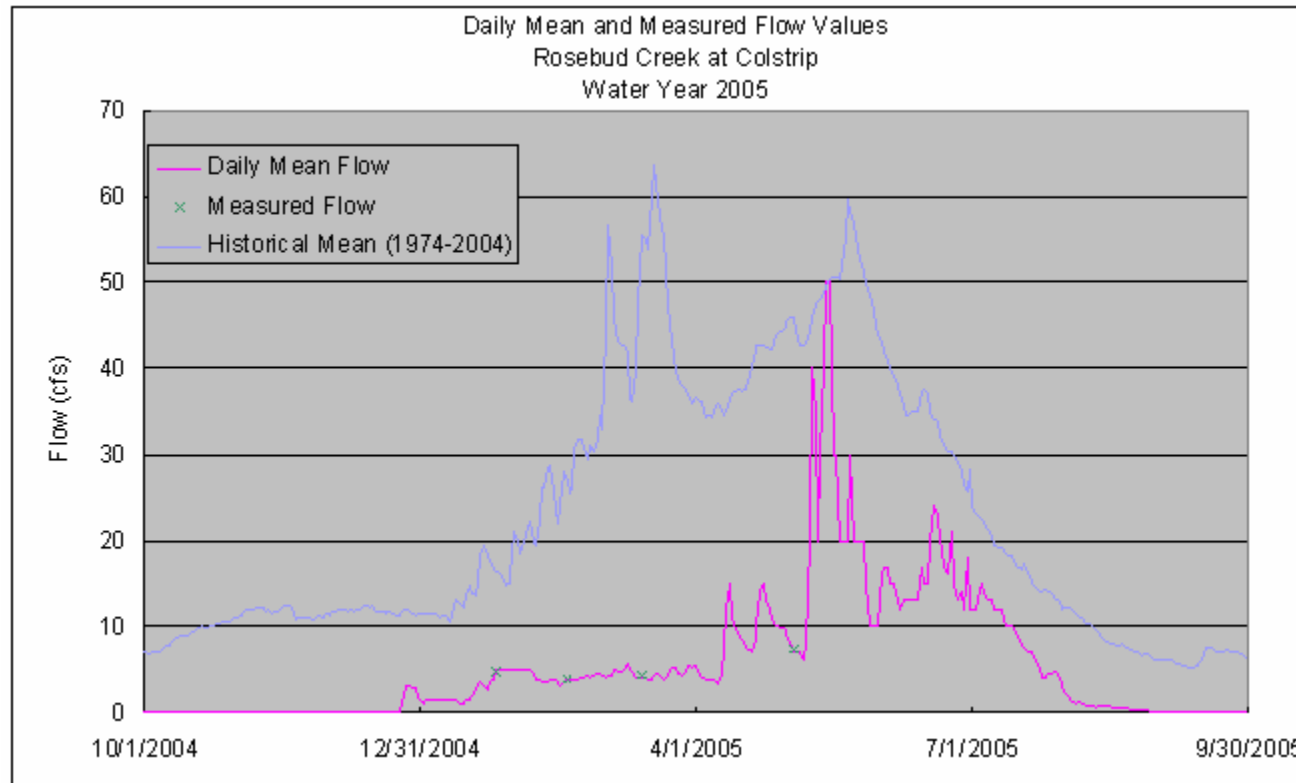


Figure 8 shows mean daily and field measurements of flow in a time series plot for water year 2005 for Rosebud Creek near Colstrip. Mean daily flow values ranged from 0 to 50 cfs. The historical mean daily flow values are also shown to place the data in context.

Figure 9: Rosebud Creek near Colstrip

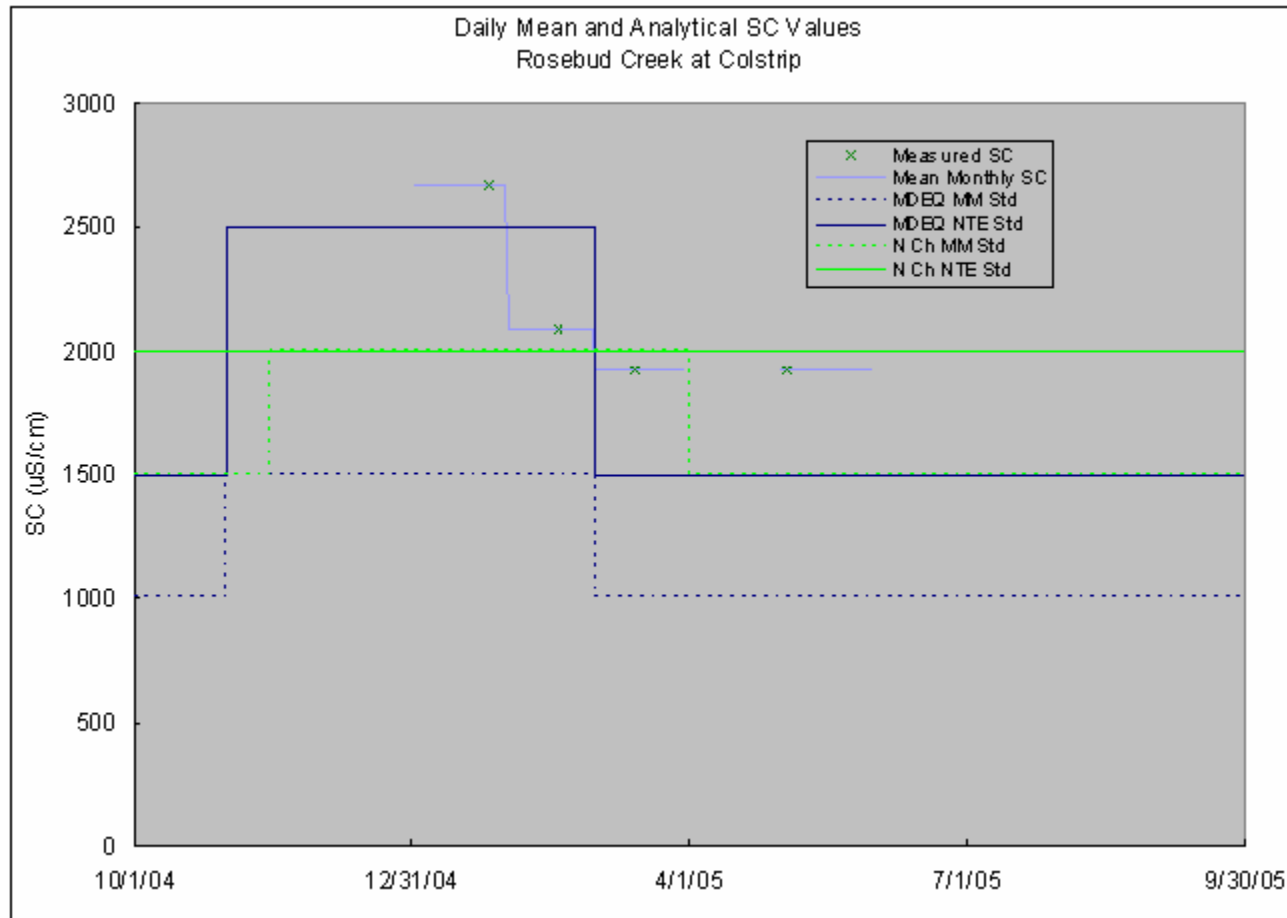


Figure 9 shows analytical SC values in a time series plot for water year 2005 for Rosebud Creek near Colstrip. Mean Monthly SC values are also shown. SC values ranged from 1920 uS/cm to 2670 uS/cm. MDEQ and Northern Cheyenne standards are also displayed for comparison. SAR values were not collected at this station in water year 2005.

Figure 10: Rosebud Creek near Colstrip

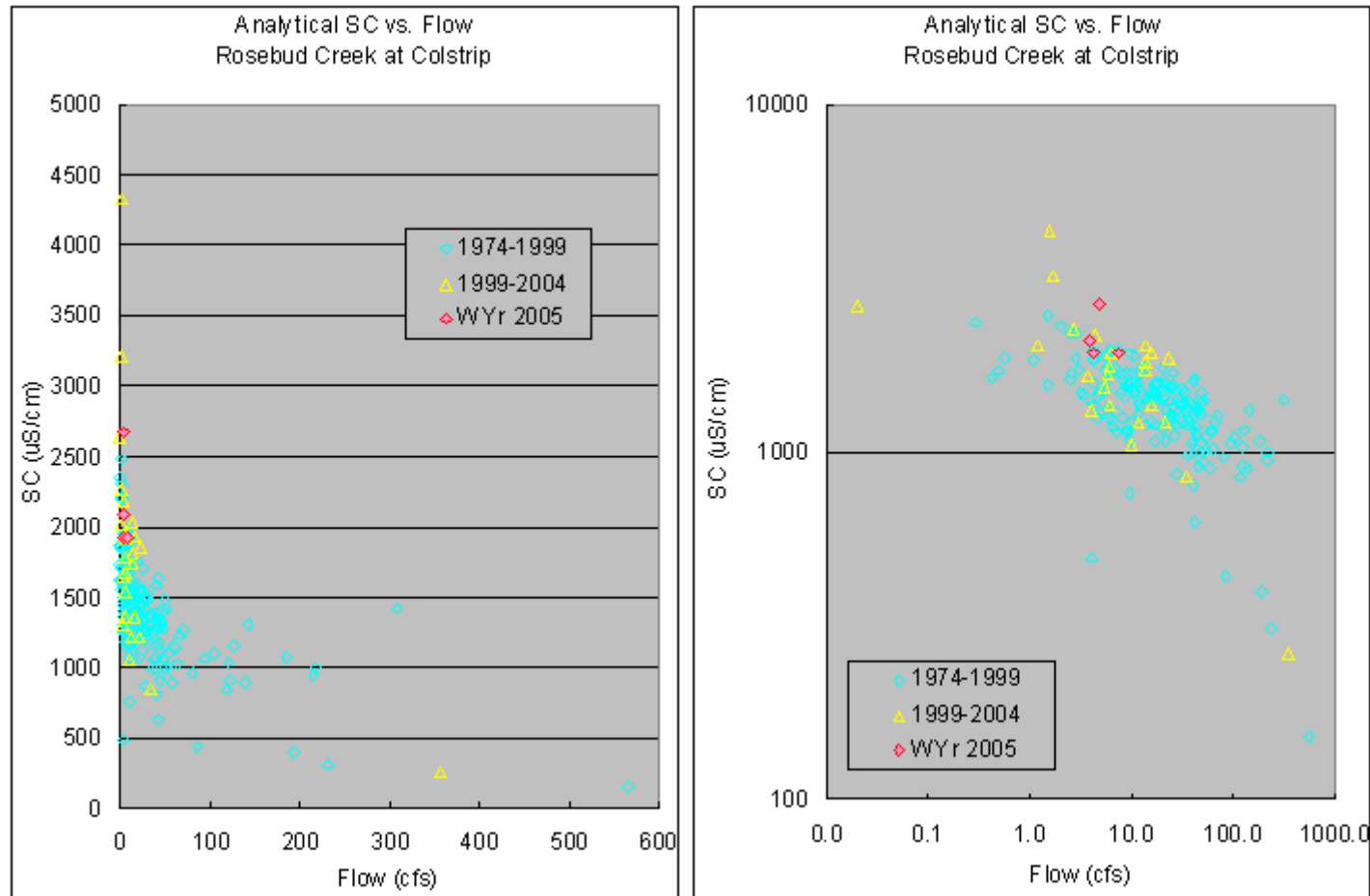


Figure 10 shows analytical SC vs. Flow data for water year 2005 for Rosebud Creek near Colstrip. These data are charted on both linear (A) and logarithmic (B) scales. Historical SC vs. Flow data are also shown to place the data in context.

Figure 11: Rosebud Creek near Rosebud

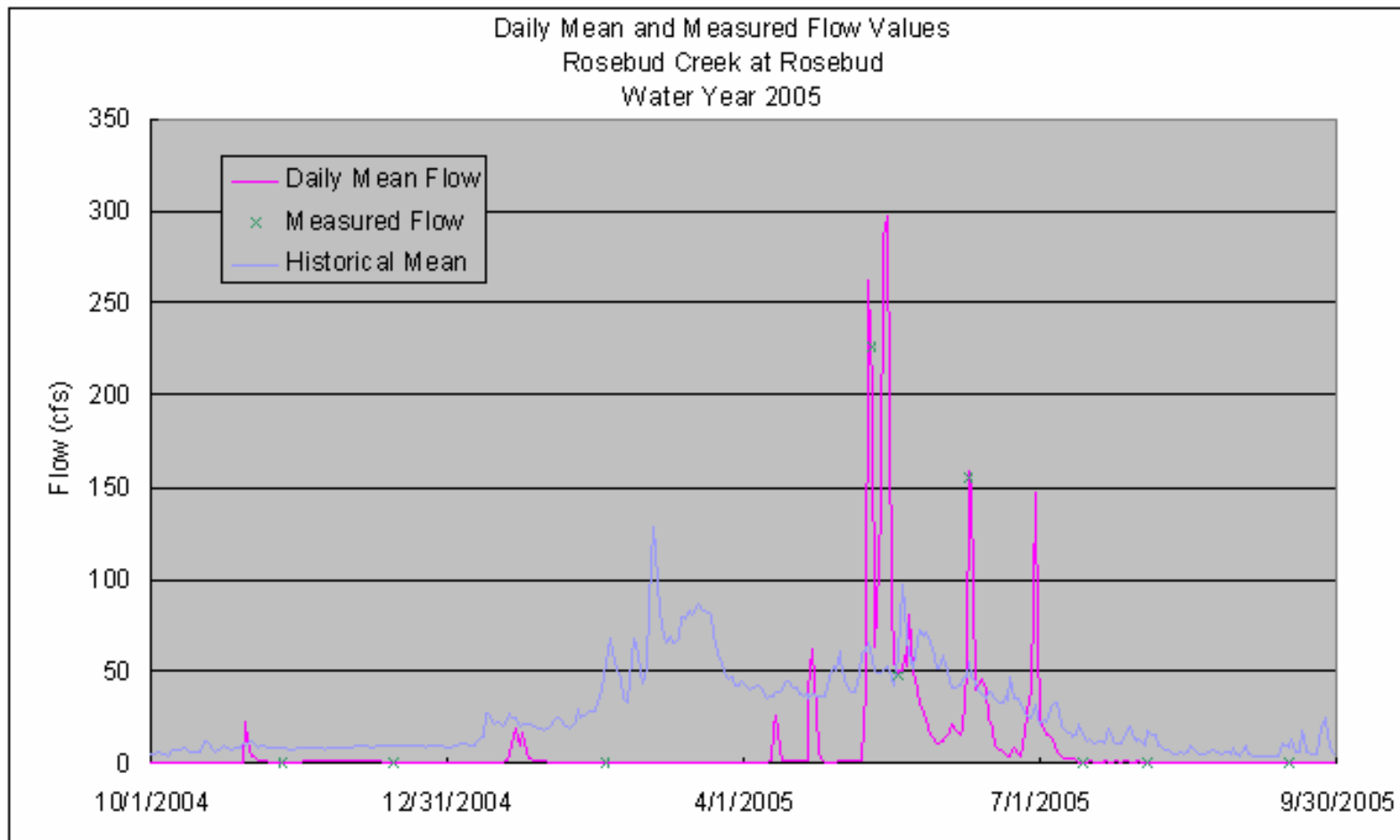


Figure 11 shows mean daily and field measurements of flow in a time series plot for water year 2005 for Rosebud Creek near Rosebud. Mean daily flow values ranged from 0 to 297 cfs. The historical mean daily flow values are also shown to place the data in context.

Figure 12: Rosebud Creek near Rosebud

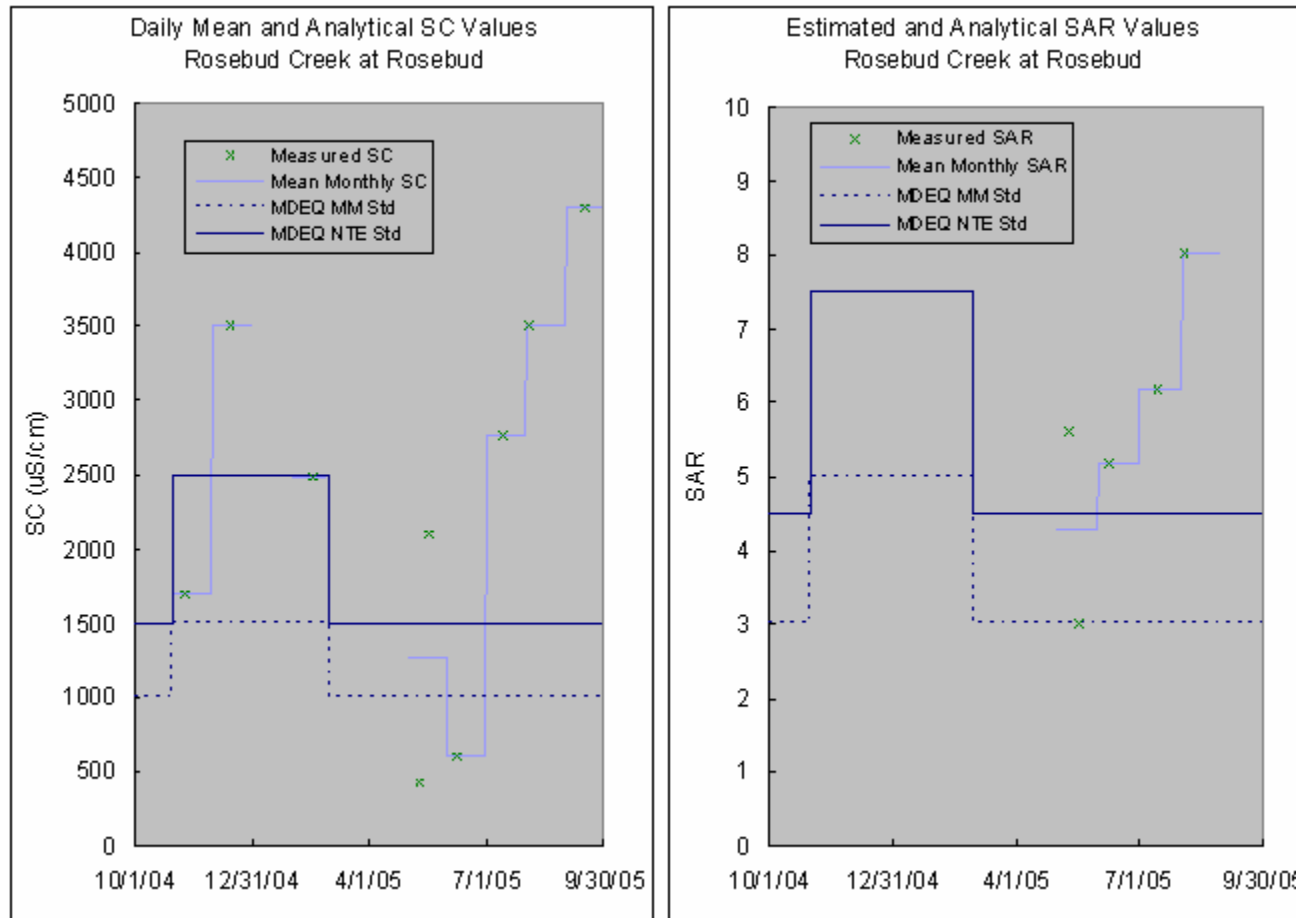


Figure 12 shows analytical SC values (A) and analytical SAR values (B) values in time series plots for water year 2005 for Rosebud Creek near Rosebud. Monthly Mean SC and SAR values are also shown. SC values ranged from 427 to 4300 uS/cm. SAR values ranged from 3.0 to 8.0. MDEQ and Northern Cheyenne standards are also displayed for comparison.

Figure 13: Rosebud Creek near Rosebud

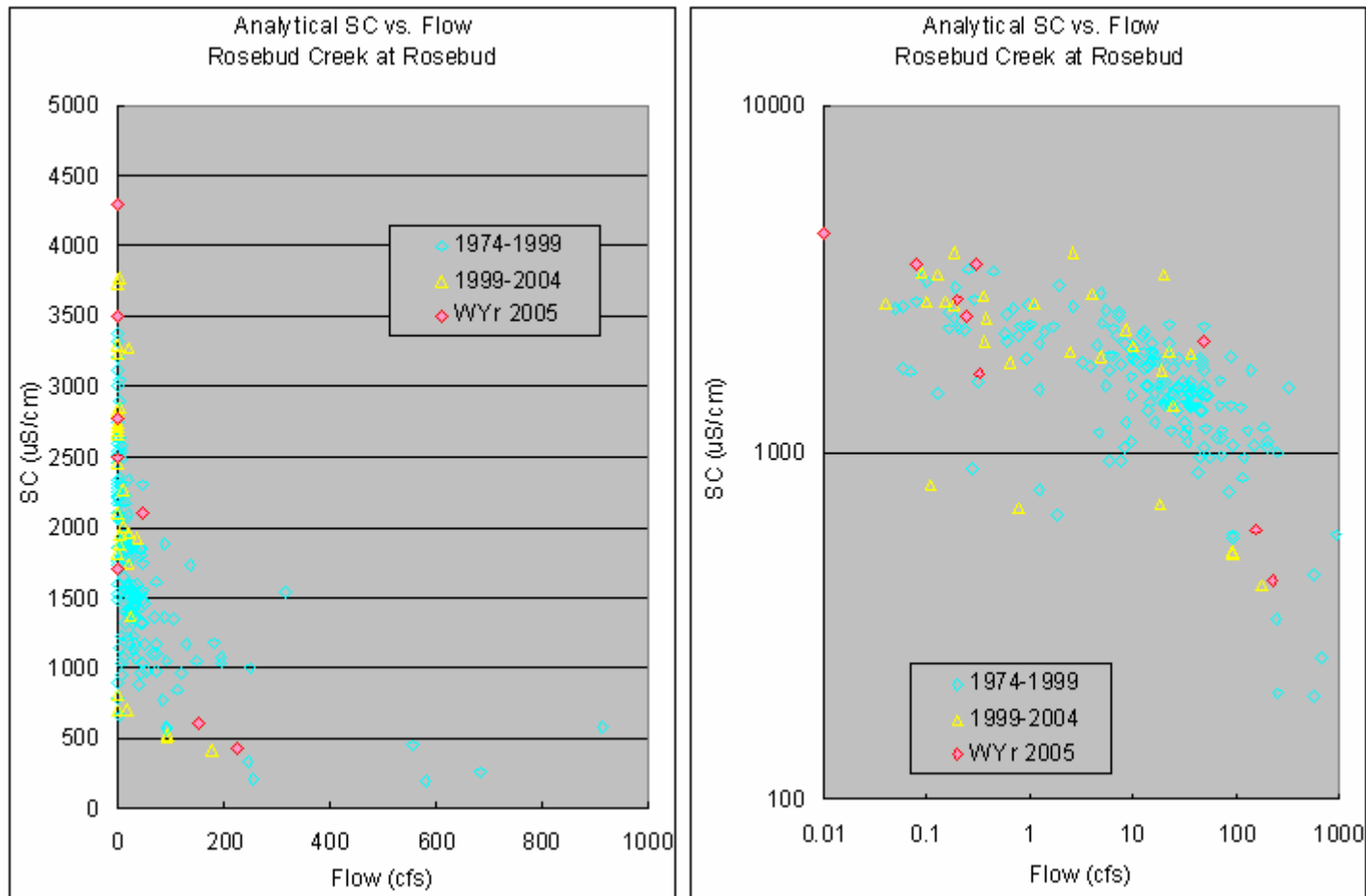


Figure 13 shows analytical SC vs. Flow data for water year 2005 for Rosebud Creek near Rosebud. These data are charted on both linear (A) and logarithmic (B) scales. Historical SC vs. Flow data are also shown to place the data in context.

Figure 14: Rosebud Creek near Rosebud

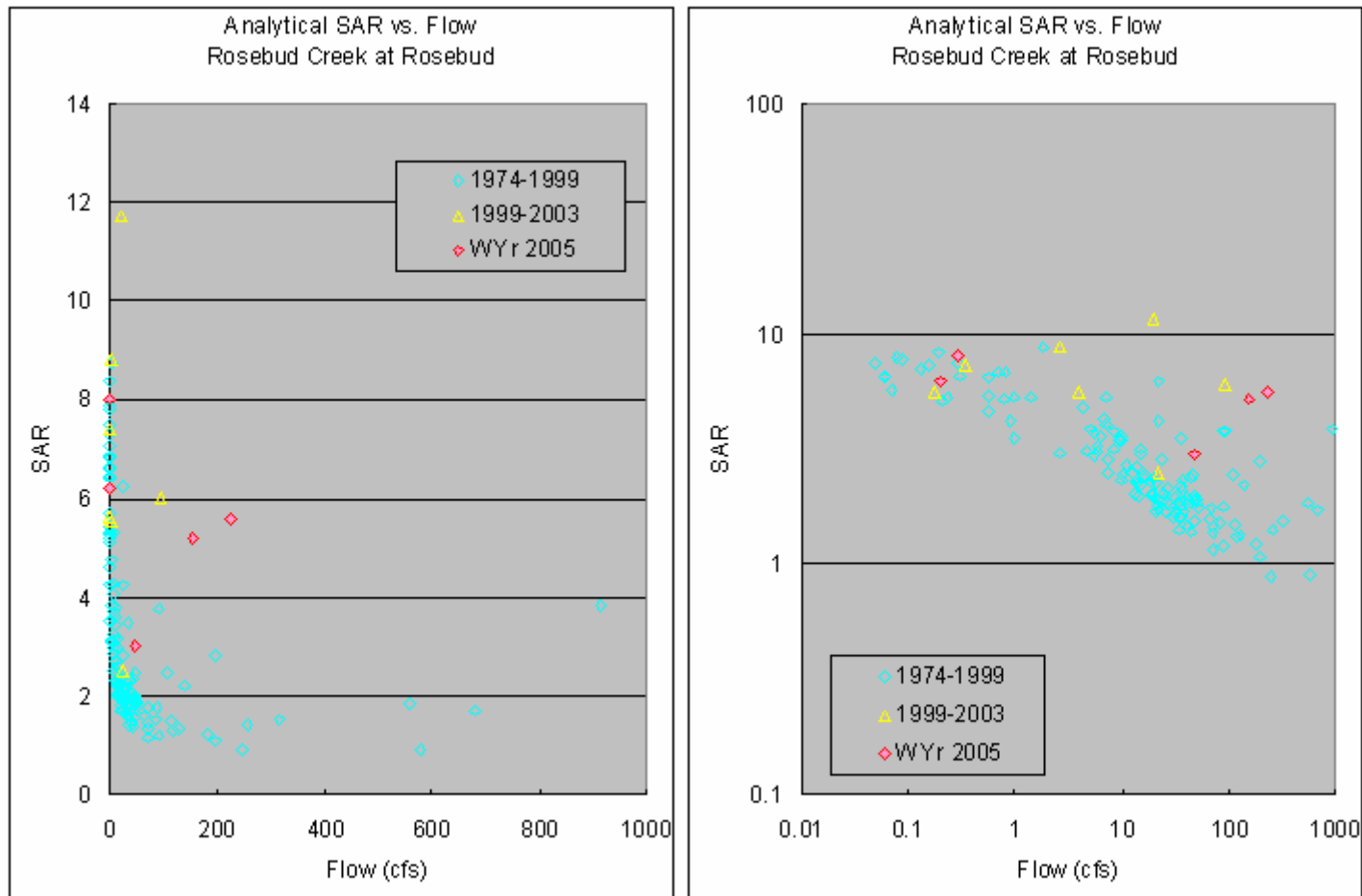


Figure 14 shows analytical SAR vs. Flow data for water year 2005 for Rosebud Creek near Rosebud. These data are charted on both linear (A) and logarithmic (B) scales. Historical SAR vs. Flow data are also shown to place the data in context.

Figure 15: Rosebud Creek near Rosebud

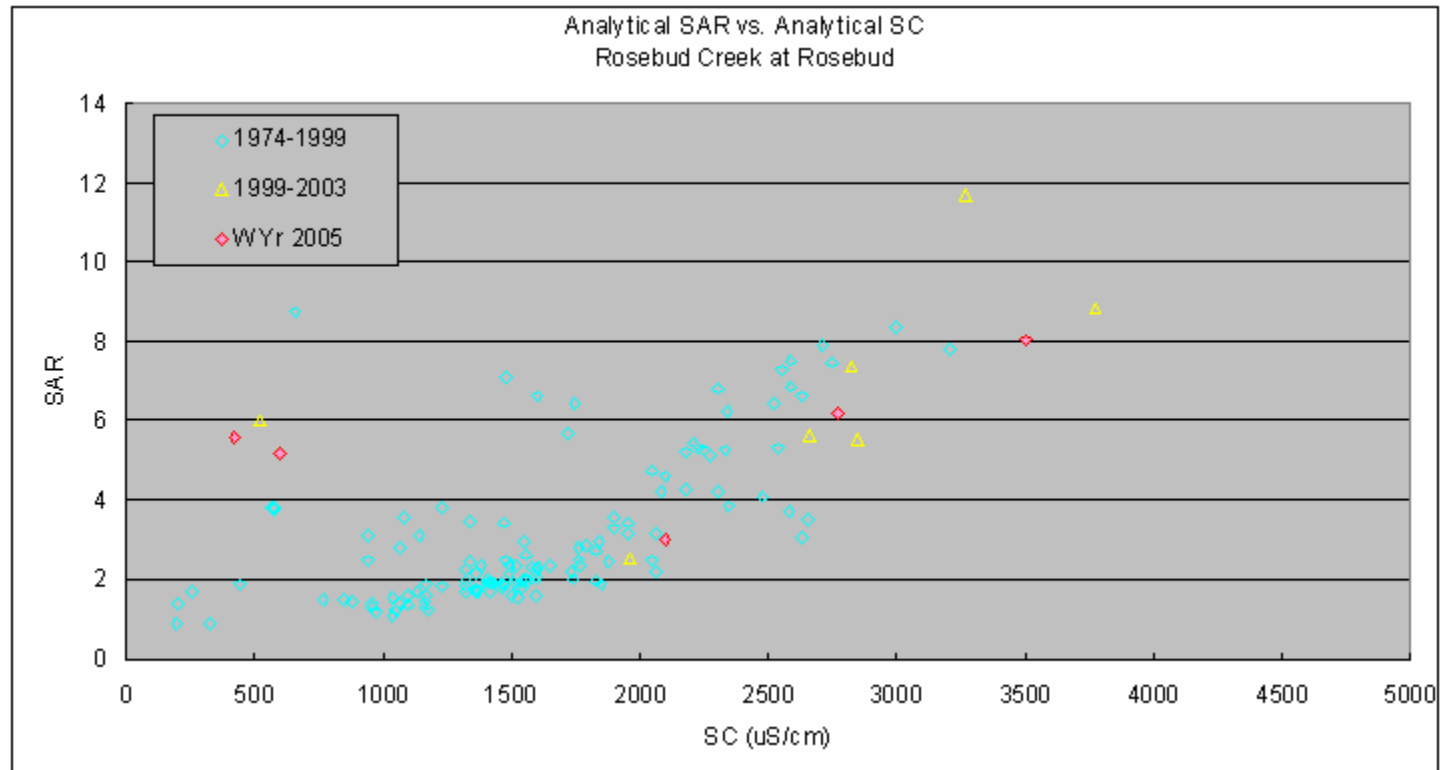


Figure 15 shows analytical SAR vs. analytical SC data for water year 2005 for Rosebud Creek near Rosebud. Historical SAR vs. SC data are also shown to place the data in context.